NATIONAL TRANSPORTATION SAFETY BOARD

Office of Marine Safety
Washington, DC

October 22, 2020

Investigator-in-Charge Factual Report

1. EVENT SUMMARY

Location: Houston Ship Channel between buoys 74 and 74a.

Date: May 10, 2019

Type: Collision

NTSB #: DCA19FM033

2. NTSB INVESTIGATION TEAM AND PARTY MEMBERS

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Contents

1 Overview

On Friday, May 10, 2019, at 1516 local time, the 754-foot-long liquified gas carrier *Genesis River* collided with a 297-foot-long tank barge being pushed ahead by the 69-foot-long towing vessel *Voyager* (figure 1).[1] The collision breached two cargo tanks in the barge, spilling petrochemical cargo into the waterway, and caused a second barge in the *Voyager* tow to capsize.

Figure 1. Screen capture from wheelhouse video on board the *Voyager* at the moment that the *Genesis River* struck barge *30015T*. (Source: Kirby Inland Marine, LP)

Before the collision, the *Genesis River* had been outbound on the Houston Ship Channel when, at 1512, it met the inbound 740-foot-long liquified gas carrier *BW Oak* in the intersection of the Houston Ship Channel and the Bayport Ship Channel. After the *Genesis River* and the *BW Oak* passed each other port side to port side in the southern end of the intersection, the *Genesis River* approached a 15.7-degree port turn in the channel. As it entered the turn, the *Genesis River*'s heading swung to port, and, although the pilot at the conn of the vessel applied counter (starboard) rudder, the vessel continued swinging to port and began to cross over to the opposite side of the channel. In the inbound barge lane ahead of the *Genesis River*, the *Voyager* was pushing two tank barges breasted together side-by-side. The *Genesis River* pilot radioed the relief captain at the helm of the *Voyager*, requesting that the towing vessel cross the tow to the other side of the channel so that the vessels could pass starboard side to starboard side. The *Voyager* relief captain agreed and turned the tow to port.

[1] A liquified gas carrier is a type of tank ship that has been designed to carry gases such as natural gas, propane, or butane in liquified form in insulated, pressurized, and/or refrigerated tanks.

Figure 2. The accident location, as shown by the red triangle. (Map data by Google Maps)

The *Genesis River* continued across the channel until it reached the opposite bank. The ship entered the barge lane and then swung back to starboard toward the main channel and the *Voyager* tow. The *Voyager* was still attempting to cross the channel with the tow, and as the *Genesis River* swung to starboard, its bow struck the starboard barge in the tow, penetrating through the barge's double hull and breaching its center cargo tanks. The force of the collision with the starboard barge capsized the port barge in the tow, and the *Voyager* heeled considerably before its face wires parted and the vessel righted itself. About 11,000 barrels of reformate, a gasoline blending stock, spilled into the waterway from the starboard barge's breached cargo tanks.

The Houston Ship Channel was closed to navigation for two days during response operations and did not fully open for navigation until May 15. There were no injuries reported as a result of the accident. The total cost of damages to the *Genesis River* and the barges was estimated at $3.2 million. The cost of reformate containment and cleanup operations totaled $12.3 million.

2 Background Information

2.1 The Vessels

2.1.1 *Genesis River*

The *Genesis River* was a Panama-flagged liquified gas carrier owned by FPG Shipholding Panama 47 S.A. and managed and operated by K-Line Energy Ship Management Co. Ltd. It was classified by the American Bureau of Shipping (ABS).[2] Built in Sakaide, Japan, by Kawasaki Heavy Industries, Ltd, the *Genesis River* was delivered in November 2018, less than 6 months before the accident. The vessel had an overall length of 754 feet (229.9 m) and a breadth of 122 feet (37.2 m). On the date of the accident, it had a nearly full load of liquid propane gas (LPG) giving it a displacement of 69,249 long tons (70,360 MT). When the *Genesis River* got under way for the voyage, it was on an even keel at a draft of 36.8 feet (11.2 m). The *Genesis River* had a crew of 28 on board, as well as 2 Houston Pilots.

Figure 3. *Genesis River* under way in Bolivar Roads near Galveston, Texas, two weeks after the accident. (Source: William J. Leach, Jr.)

Unlike most tank vessels of its size, the *Genesis River* did not have a bulbous bow. Rather, the vessel was designed with Kawasaki Heavy Industries' proprietary "SEA Arrow" bow shape, which according to the company provided improved propulsion performance by reducing bow wave resistance. The vessel also had a unique rudder employing a "bulb system with fins" designed to reduce fuel consumption. The *Genesis River*'s main propulsion was provided by a 17,567 hp (13,100 kW) Kawasaki-MAN B&W 7S60ME-C8.2 diesel engine directly coupled to a single fixed-pitch propeller. (See section 6.5.1 for detailed information regarding the *Genesis River* main propulsion system.) According to the vessel's deck log, the rudders and engines were tested

[2] *Classification societies* such as ABS are nongovernmental organizations that establish and maintain standards for shipbuilding and operations. They may also be delegated by a flag state to perform certain flag-state vessel inspection and certification functions.

satisfactorily prior to getting under way on the accident date. The pilot card—a three-page summary of the ship's particulars, engine speeds, and steering and navigation equipment—noted that the time for the rudder to move from hard-over to hard over (35° to 30°) was 24 seconds with one steering pump on line and 13 seconds with 2 steering pumps online, which was within the Coast Guard mandated swing rate.[3] The crew reported no mechanical issues during the voyage.

2.1.2 *Voyager* and Tow

The towing vessel *Voyager* was owned and operated by Kirby Inland Marine, LP. ABS was designated as the "third party organization" for the purpose of validating compliance with Coast Guard regulations, and the vessel's last survey was completed in December 2018. The *Voyager* had a valid certificate of inspection issued by the Coast Guard in January 2019. Built in Channelview, Texas, by Glendale Boat Works, Inc., the vessel was delivered in 1975. The *Voyager* had four previous owners before being acquired by Kirby Inland Marine in 1999. It had an overall length of 68.9 feet (21 m), a breadth of 26.1 feet (8 m), and a draft of 8.5 feet (2.6 m). The *Voyager* had a crew of 4.

Figure 4. *Voyager* moored in Channelview, Texas, following the accident.

The *Voyager* was equipped with two Cummins K38-M EPA-Tier-2-certified diesel engines, each coupled to a fixed pitch propeller via a Twin-Disc transmission, with a combined power output of 1,700 hp (1,268 kW). The engines and transmissions were controlled from the wheelhouse by a pneumatic throttle system. The vessel had two steering rudders and four flanking rudders controlled via tiller handles in the wheelhouse.[4] Although there were two tillers in the wheelhouse for the steering rudders, they were operated in tandem; that is, they could not be individually controlled and the movement of one tiller also moved the other tiller. The flanking rudders likewise had two tillers in the wheelhouse that operated in tandem.

[3] Per Title 46 *Code of Federal Regulations* subpart 58.25-10, an inspected vessel's steering machinery must be capable of moving the rudder from 35° on either side to 35° on the other with the vessel at its deepest loadline draft and running at maximum ahead service speed, and from 35° on either side to 30° on the other in not more than 28 seconds under the same conditions."

[4] *Flanking rudders* are rudders positioned forward of the propellers that increase the maneuverability of the vessel, particularly in the astern direction.

According to records provided by the company, major shipyard maintenance and repair periods were conducted on the vessel in 2010, 2013, 2016, and 2018. The main propulsion engines were overhauled in 2013, and a post maintenance thrust pad test confirmed a combined hp of 1,757.5. According to the *Voyager* crew, the rudders and engines were tested satisfactorily prior to getting under way in the morning on the accident date, and the crew reported no mechanical issues during the voyage.

The *Voyager* was pushing ahead two tank barges, the *30015T* and the *MMI3041*, which were owned and operated by Kirby Inland Marine. The unmanned barges were inspected tank vessels under Coast Guard regulations. Both were designed and constructed by Trinity Marine Products, Inc. (now Arcosa Marine Products), the *30015T* being built in Houston in 1996 and the *MMI3041* being built in Ashland City, Tennessee, in 2003. The barges were nearly identical in size and construction, each measuring 297.5 feet (90.7 m) in length and 54 feet (16.5 m) in beam. The barges were "double skin;" that is, they were built with inner and outer hulls to protect the cargo in case of a breach in an outer hull. Each barge had six cargo tanks arranged two wide by three long and separated by single bulkheads. Both barges were fully loaded with a cargo of reformate, a gasoline blending stock. Barge *30015T* was carrying 26,023 barrels of product, and barge *MMI3041* was carrying 25,392 barrels. With these loads, the barges each had a draft of 10 feet (3.1 m) and a freeboard of 2 feet (0.6 m).

During the accident voyage, the tow was configured with the two barges breasted together side-by-side, with the *30015T* to starboard and the *MMI3041* to port (see figure 1). The relief captain on the *Voyager* told investigators that this configuration was chosen for convenience, as the barges were moored side-by-side at their origin in Texas City, Texas, they would be moored in the same configuration at their intended destination of Channelview, and the distance between the two locations was relatively short. He stated that, compared to a line configuration, the side-by-side configuration made the tow slower, but it could turn faster.

2.2 The Houston Ship Channel

The Port of Houston is one of the busiest ports in the world, ranking second among US ports in terms of cargo tonnage according to the Coast Guard. In 2018, the average daily traffic in Coast Guard Sector Houston-Galveston Vessel Traffic Service Area totaled about 629 vessel transits (including tankers, freighters, tows, and ferries, among others), with nearly 40 ships docked in port.[5]

The Houston Ship Channel is about 55 nautical miles in length from the turning basin at the Port of Houston to the sea buoy offshore from Galveston. The upper channel, which runs from the turning basin to the entrance to Galveston Bay at Morgan's Point, contains numerous turns and varies in width from as little as 250 feet to over 750 feet. The lower channel transits through Galveston Bay from Morgan's Point to Bolivar Roads near Galveston. This section is comprised of longer, straight segments with a 530-foot-wide main channel dredged to a project depth of 45 feet. The lower channel also has separate barge lanes located on either side of the main channel, each 235 feet wide with a project depth of 12 feet. Navigational beacons marking the Houston Ship Channel are located to the outside of the barge lanes. Consistent with the system of navigation

[5] Tonnage and traffic statistics from US Coast Guard, *State of the Waterway 2018*, Houston, Texas, 2019, available at https://lonestarhsc.org/dir/wp-content/uploads/2019/04/SWW2019.pdf. Accessed February 21, 2020.

aids used throughout the Western Hemisphere and other locations, the navigational buoys and beacons marking the right side of the Houston Ship Channel are green and those marking the left side are red, as viewed from an outbound vessel. For the remainder of this report, "red side" and "green side" will be used to describe a vessel's position relative to the center of the channel, where applicable.

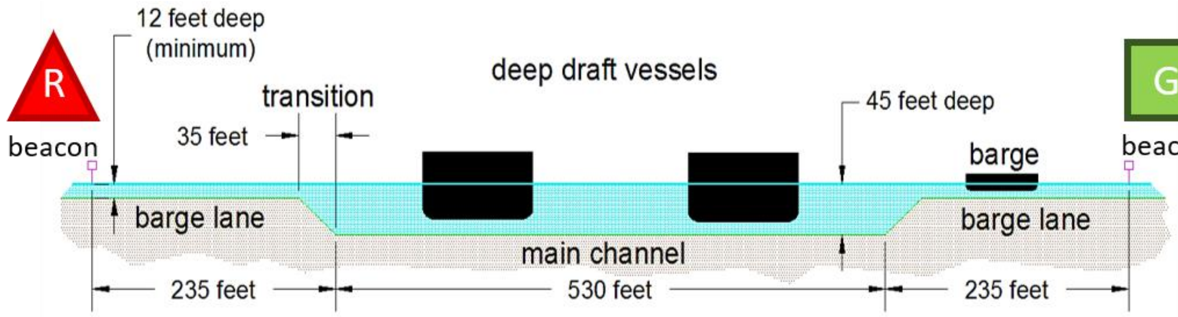

Figure 5. Houston Ship Channel profile, with navigation beacons as viewed by an outbound vessel.

In the northern Galveston Bay, the Houston Ship Channel is intersected from the west by the Bayport Ship Channel, which provides access to container, automobile, and petrochemical terminals in Bayport, Texas. Where the two channels intersect, the Bayport channel widens into a funnel shape to allow ships to negotiate the turn from one channel to the other. This area is known as the "Bayport Flare." At the southern terminus of the Bayport Flare, in the vicinity of Five Mile Cut (a shallow channel that extends to the east of the Houston Ship Channel), the Houston Ship Channel makes a 15.7 degree turn to the east. In 2017, the southern side of the Bayport Flare and the eastern side of the turn at Five Mile Cut were dredged by the US Army Corps of Engineers, widening the flare and the channel in this area so that large inbound vessels can more safely navigate both the turn at Five Mile Cut and the turn into the Bayport channel.

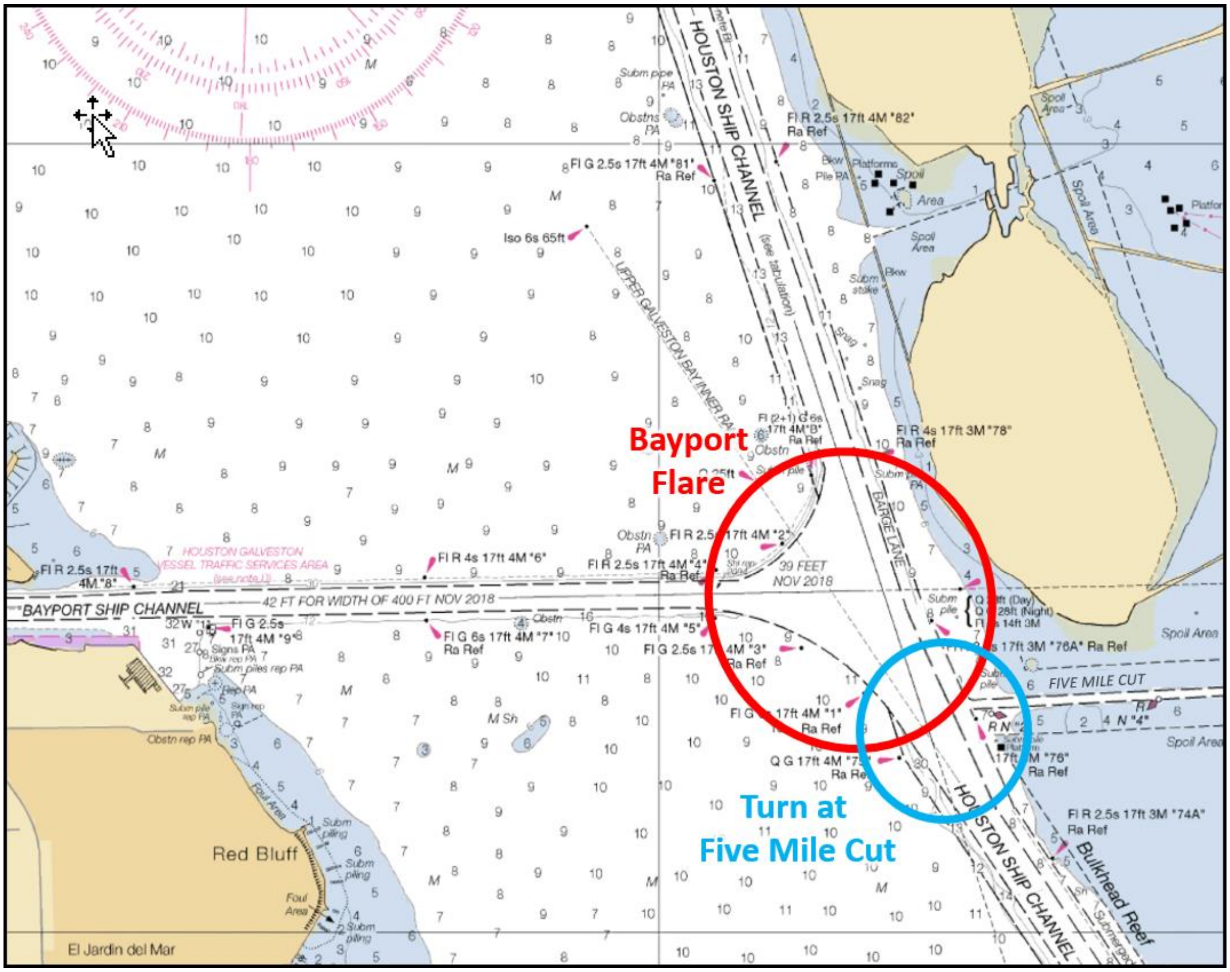

Figure 6. Bayport Flare and turn at Five Mile Cut (Background adapted from National Oceanic and Atmospheric Administration [NOAA] chart 11327[6])

The Army Corps of Engineers is responsible for maintaining the Houston Ship Channel at its authorized width and depth by conducting periodic dredging operations. The frequency of dredging varies, with areas that historically shoal at a faster rate being dredged at shorter intervals. A Corps of Engineers representative stated that the periodicity of dredging is also dependent on available funding. Dredging plans are updated as needed based on regular depth sounding surveys of the channel. Surveys are conducted at intervals not less than 6 months and can also be requested on an ad hoc basis by the Coast Guard, the Houston Pilots, or other users of the channel. Figure 7 below shows the January 2019 periodic survey results for the turn at Five Mile Cut. Blue tones indicate deeper water, while yellow/red tones indicate shallower water. The sounding data in feet are indicated by the numbers in the image. Figure 8 shows the results of a survey that was requested by the Houston Pilots immediately following the accident in May 2019. Note that the May survey shows some shoaling had occurred in the turn in the 4 months since the January periodic survey.

[6] Channel borders on NOAA chart 11327 do not reflect a brief widening of the Houston Ship Channel on the eastern side of the turn at Five Mile Cut. The NTSB has modified this chartlet and other instances of chart 11327 throughout this report to reflect the widening based on a US Army Corps of Engineers drawing of the widening dredge plan. The locations of selected feature labels within the chart have also been adjusted to for readability and simplicity.

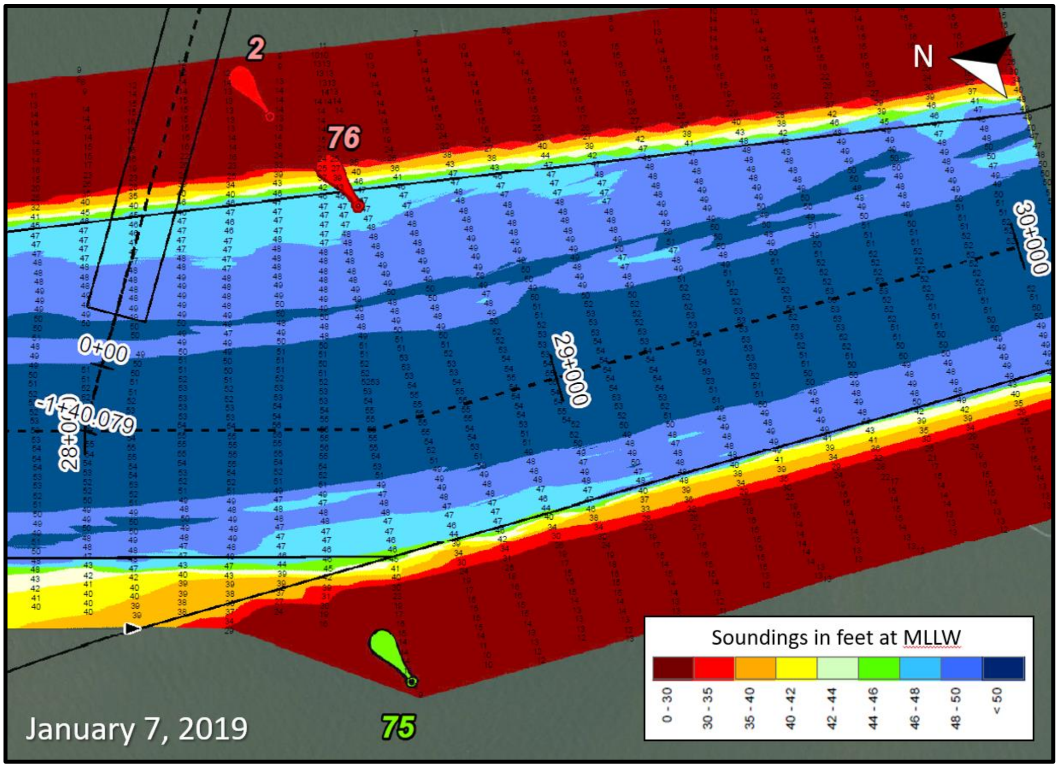

Figure 7. January 2019 sounding survey data for the Houston Ship Channel at the turn at Five Mile Cut. (Source: Army Corps of Engineers)

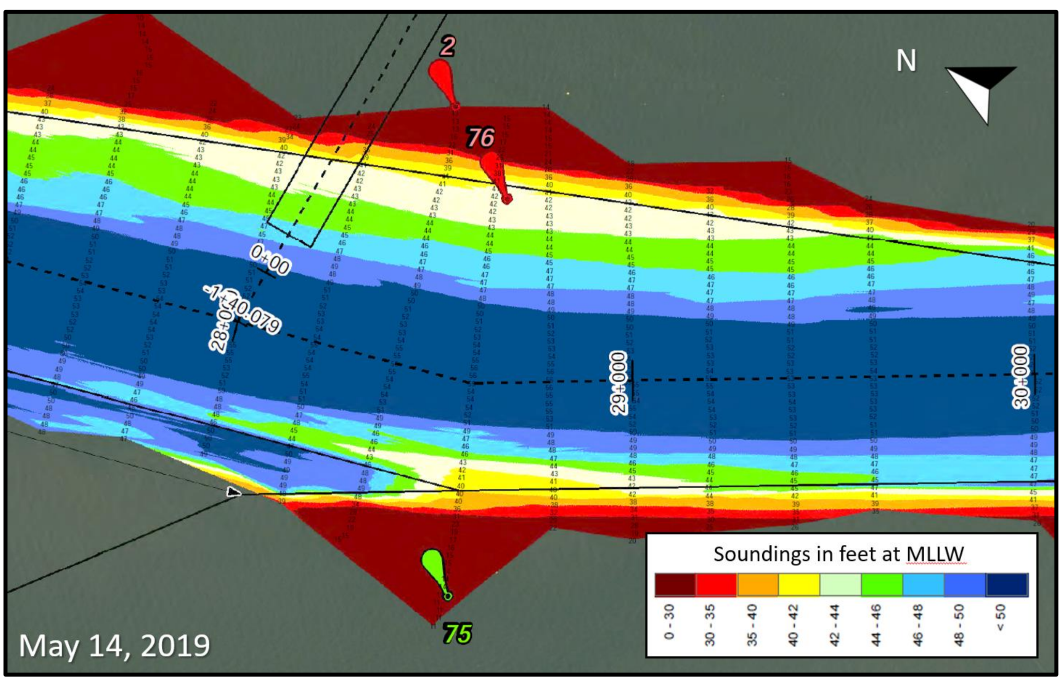

Figure 8. May 2019 sounding survey data for the Houston Ship Channel at the turn at Five Mile Cut. (Source: Army Corps of Engineers)

When asked by investigators, a Corps of Engineers representative confirmed that shoaling was common in turns of the channel. She also stated that the area of the channel in the vicinity of the Bayport Flare and just south of the flare was prone to shoaling, but that it was "not one that is commonly brought up as a concern." Prior to the accident, the channel in the vicinity of the turn at Five Mile Cut had last been dredged in late 2017. In November 2019 (5.5 months after the accident), planned maintenance dredging of the Houston Ship Channel in this area commenced.

3 The Accident

On the morning of May 10, 2019, the *Genesis River* was berthed at the Targa Resources Galena Park Marine Terminal, located just east of Houston, Texas, on the upper Houston Ship Channel. The vessel was scheduled to get under way at noon following a full onload of liquid propane gas (LPG) cargo.

Two pilots were assigned to the *Genesis River* for the transit outbound on the channel, in accordance with a guidance document known as the *Houston Pilots Working Rules, Including Navigation Safety Guidelines for the Houston Ship Channel*.[7] Members of the pilots' association stated that the two-pilot policy was put in place to prevent fatigue while handling "wide-bodied vessels" (vessels whose width exceeded 120 feet) for extended periods. Each pilot normally conned the vessel for about half of the transit. Neither pilot held authority or seniority over the other pilot, and each acted independently while at the conn (unless the conning pilot specifically requested the assistance of the other).

The two assigned pilots met at the Targa Terminal, boarded the *Genesis River*, and were escorted to the ship's bridge, arriving at 1148. The pilot who would conn the vessel first (hereafter known as pilot 1) requested and was given the pilot card. While pilot 1 reviewed the card, the second pilot (pilot 2) set up a portable pilot unit (PPU).[8] The master of the vessel arrived about 2 minutes later and greeted pilot 1.

As the bridge team prepared to get under way, pilot 2 requested that the crew turn off all alarms "on the radar," telling the crew that since the vessel would be passing other vessels at short distances throughout the transit, the alarms indicating closest point of approach (CPA) would be near constant and would be a distraction. The *Genesis River* management company's safety management system (SMS) required that both of the ship's radars be kept on at all times while in areas of high traffic density and near navigational hazards. However, the master told investigators that the alarms on the vessel's automated radar plotting aid (ARPA) system that displayed the radar data could not be turned off, so to comply with pilot 2's request to silence alarms, he instructed the officer of the watch (the fourth officer) to put the radars in standby.[9] The SMS also required that the vessel's electronic charting, display, and information system (ECDIS) be regularly monitored, but the master stated that alarms on this system likewise could not be silenced, so he told the fourth officer to turn off the ECDIS as well. The *Genesis River* had two ECDISs on board

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[7] The Houston Pilots' guidance is updated regularly, and its current version, approved on December 4, 2019, is now known as the *Houston Pilots Navigation Safety Guidelines for the Houston Ship Channel*.

[8] A *PPU* is a compact laptop computer or tablet with electronic navigation and charting software that pilots use for navigation, in addition to the vessel's own navigation equipment. PPUs normally are equipped with an independent GPS antenna, as well as a plug that allows the unit to access information from the ship's installed systems such as GPS and AIS

[9] *Standby* is a condition of a radar where it is energized but not rotating or radiating. When in standby, no information is provided by the radar.

in order to meet the *International Convention for the Safety of Life at Sea* (SOLAS) requirements for redundancy; it did not carry paper navigation charts.[10] With both ECDISs off, the master instructed the fourth officer to monitor the vessel's position visually by sighting landmarks, navigation buoys, and beacons and by monitoring the pilot's PPU. Pilot 1 told investigators that he was aware that the ECDIS was off and that the radars were in standby, but he was not concerned because he had the PPU to rely on and had good visibility with which to see navigation aids.

Pilot 1 asked the master if all of the ship systems were in working order, and the master replied affirmatively but that the main engine had not yet been tested. Immediately thereafter, the *Genesis River*'s voyage data recorder (VDR) captured an alarm sounding from the vessel's engine order telegraph, indicating that the engine testing was in progress.[11] The VDR bridge audio recording did not capture any discussion between the master and the pilot regarding the handling characteristics of the vessel or the passage plan prepared by the crew.

After waiting for the channel to clear of other vessels, the *Genesis River* took in lines and got under way with the assistance of two tugboats. At 1222, pilot 1 issued his first rudder order to the helmsman. The helmsman repeated the order, turned the wheel to the ordered angle, and then repeated the order again when the rudder reached the desired angle. (Because the rudder on a ship has a large surface area and must be moved through the water by hydraulic machinery, the movement of the rudder will lag behind the rudder input—the ship's wheel—with the lag time dependent on the amount of change in the rudder position.) The pilot then instructed the helmsman to only repeat his order once, when the pilot issued an order. Pilot 1 stated that he preferred this format to reduce noise distraction, and he verified the position of the rudder after issuing an order by sighting the rudder angle indicator, an instrument visible from any position on the bridge that displayed the position of the rudder.

Pilot 1 told investigators that within the first few turns in the channel, he determined that the ship had "a small rudder" and responded sluggishly to the rudder commands. He stated, "I needed to use 20 degrees and 30 degrees rudder to make any course changes."

After a short time, pilot 2 departed the bridge, eventually proceeding to the pilot room, a small lounge and bunkroom located behind the wheelhouse, at 1245. About the same time, the *Genesis River*'s second officer arrived on the bridge to relieve the fourth officer as officer of the watch. When he arrived on the bridge, the second officer noted that the ECDIS was off and that the radars were in standby. The master told him why the equipment was secured and instructed him to continue monitoring the *Genesis River*'s position visually. When interviewed after the

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[10] The SOLAS Convention is generally regarded as the most important of all international treaties concerning the safety of merchant ships. The main objective of the convention is to specify minimum standards for the construction, equipment, and operation of ships, compatible with their safety. Flag states are responsible for ensuring that ships under their flag comply with its requirements. The first version of the SOLAS Convention was adopted in 1914 in response to the Titanic disaster. The current version in force is the 1974 Convention, as amended on numerous occasions. Source: International Maritime Organization (IMO), International Convention for the Safety of Life at Sea (SOLAS), 1974, http://www.imo.org/en/About/Conventions/ListOfConventions/Pages/International-Convention-for-the-Safety-of-Life-at-Sea-(SOLAS),-1974.aspx.

[11] *VDR*s maintain continuous, sequential records of data relating to a ship's equipment and its command and control, and capture bridge audio from certain areas in the pilothouse and on the bridge wings. Regulation 20 of the *International Convention for the Safety of Life at Sea* (SOLAS) Chapter V requires all passenger ships and all cargo ships of 3,000 or more gross tons (International Tonnage Convention), built on or after July 1, 2002, to carry VDRs.

accident, the second officer, who was the ship's navigator, stated that he was concerned about the status of the ECDIS and radars but did not question the master's decision.

Sometime after 1300, the master called the *Genesis River* chief officer to the bridge to relieve him as the senior officer on deck so that the master could eat lunch. The *Genesis River* management company's SMS normally required the master to be on the bridge while the ship was under pilotage but allowed the chief officer to relieve the master during long navigational transits. The *Genesis River* master told investigators that he trusted the chief officer, who held a master's credential, and often turned the bridge over to him during long transits, including the Houston Ship Channel. Pilot 1 stated that it was not unusual for a master to leave the bridge during a transit of the Houston Ship Channel, and he was comfortable with a chief officer standing in for a master.

Before leaving the bridge, the master briefed the chief officer on the status of the ECDIS and radars, and once again instructed the crew to monitor the ship's position visually. According to the master and chief officer, the master then introduced the chief officer to pilot 1, although, when interviewed after the accident, pilot 1 did not recall the chief officer being on the bridge or the introduction. The master told the chief officer that he would return to the bridge around 1500.

As the *Genesis River* transited through the upper Houston Ship Channel, pilot 1 used varying speeds between dead slow ahead and half ahead combined with large rudder angles to navigate through the multiple turns in the first half of the voyage. In a straight section of the channel south of the ferry landing at Lynchburg, Texas, the pilot increased speed to full ahead for a brief period "just to see how the ship would respond." The vessel's speed reached 9.6 knots before the pilot slowed the ship in preparation for passing a barge terminal.

At 1411, the *Genesis River* met the inbound *Stolt Inspiration*, a 580-foot partially laden tanker. Pilots navigating large vessels meeting head-on in a narrow channel such as the Houston Ship Channel use a maneuver colloquially known as the "Texas Chicken" to safely pass. When the vessels are about 0.5 miles from each other, and if the pilots have agreed to a port-to-port meeting, each pilot applies a starboard rudder of about 3 to 6 degrees. The water that is being displaced by the vessels' bows (known as bow cushion) then helps push the ships away from each other and away from the channel's centerline during the meeting. After the ships pass each other, the suction of the displaced water flowing back in behind them, combined with pressure from the water compressed along the starboard channel bank (known as bank cushion) naturally forces the vessels' bows back toward the center of the waterway. At the same time, an area of low pressure between the channel bank and the stern of each vessel tends to hold the stern toward the channel bank (a force known as bank suction). As the bow swings to port (during a port-to-port passing), the pilots may use a counter rudder order (starboard rudder during a port-to-port passing) to stop the swing caused by these forces on each ship. The amount of counter rudder depends on the as-loaded maneuvering characteristics of the vessel. Pilot 1 told investigators that in order to stop the swing of the *Genesis River* after passing the *Stolt Inspiration*, he had to use hard starboard (35 degrees) rudder. Additionally, he had to use an "engine kick"—a temporary increase in engine rpm to increase water wash over the rudder to improve its effectiveness.

Pilot 2 returned to the bridge about 1440 in preparation for taking the conn from pilot 1 near Morgan's Point, where the Houston Ship Channel enters Galveston Bay. Pilot 2 stated that when he arrived, he listened to the radio communications to get a sense of the vessel traffic. He also observed pilot 1 as he maneuvered the *Genesis River* past the inbound 600-foot-long tanker *Marvel*. Regarding the passing with the *Marvel*, pilot 1 stated "once again, I had to use a kick to get the [*Genesis River*] to stop swinging after I met the ship."

At 1444, pilot 2 took the conn from pilot 1, stating "I got you." He then ordered the helmsman to "steady," which was acknowledged by the helmsman. As he had been instructed by pilot 1, the helmsman continued to only repeat the rudder order once; he did not say the order again when the ship was steadied on course. After pilot 2 issued the order, he asked pilot 1, "Y'all over the place?" Pilot 1 responded, "Yup," and added, "She's takin' lotsa wheel…typical Japanese ship; got a little bitty rudder on her." Pilot 1 then told pilot 2 about the next two inbound ships that the *Genesis River* would meet, as well as other vessel traffic in the area.

Pilot 1 remained on the bridge for the next 15 minutes, carrying on a conversation with pilot 2 about various topics, including an extended discussion about the handling characteristics of ships such as the *Genesis River*. The pilots expressed concerns about large ships that responded sluggishly, and both noted that if they were following another ship they allowed extra distance to ensure that they could steady up each time they met the next ship head-on. Pilot 2 stated, "Yeah, I've sweated a couple times not knowing if they were gonna check-up [stop swinging] after meetin' a widebody there." During the conversation, pilot 2 issued helm and engine commands to the *Genesis River* crew, occasionally interrupting his discussion with pilot 1 to issue an order.

At 1448, as the *Genesis River* was clearing Morgan's Point and steadying on its first long leg of the Galveston Bay section of the channel, pilot 2 asked, "Mate or captain, [do] you have a 10-minute notice we can increase to?" The second mate responded, "yes" and 15 seconds later asked, "do you want me to increase now?" Pilot 2 answered "yes; that would be great." In this exchange, pilot 2 was asking the ship to set the engine at what is commonly referred to as "sea speed," or, as it was labeled on the *Genesis River*'s engine order telegraph, "Nav. Full." On a commercial vessel with a direct-propulsion slow-speed diesel engine, when a range of engine orders is required, such as when entering and leaving port, the vessel's engine is normally placed in *maneuvering mode*. The engine room is generally manned when in maneuvering mode, and the engine is able to respond to orders (full, half, slow and dead slow ahead, as well as astern orders) on demand. When maneuvering mode is no longer required, such as transits in open ocean, the engine is normally set at sea speed. At sea speed, the engine operates at a higher rpm, but the crew has limited ability to change rpm on demand (hence, the pilot's reference to "10-minute notice"). The rpm is governed by a control program that limits changes to protect the engine. Following pilot 2's request for sea speed, the sound of the engine order telegraph alarm was captured on the VDR audio, and the engine speed, which had been at 60 rpm, began to slowly increase.

At 1450, the *Genesis River* passed the inbound 473-foot-long tanker *Crimson Ray* port-to-port without incident. Nine minutes later, the *Genesis River* passed the inbound 440-foot-long tanker *Nordic Aki*, again without incident.

At 1500, pilot 1 left the bridge and proceeded to the pilot room. About the same time, an ordinary seaman (OS) requested permission from the *Genesis River* second officer to take the helm under the observation of the able-bodied seaman (AB) assigned to the helmsman watch. The OS told investigators that he was training for promotion to an AB position with the company (the OS held an AB certificate). The second officer gave permission, and the OS took the helm. In a deposition taken in October 2019, the AB stated that he requested permission from pilot 2 to turn over the helm to the OS. However, pilot 2 told investigators that he was not informed that the OS was at the wheel, and the VDR did not capture audio of the AB or any other crewmember requesting permission to change helmsmen. The AB stated that he stood next to the OS while he was at the helm and verified that rudder orders were properly executed.

At 1505, a pilot on the inbound liquified gas carrier *BW Oak* contacted pilot 2 via VHF radio to make passing arrangements. On VHF channel 13, the Intership Navigation Safety (Bridge-to-bridge) channel, the pilots agreed to a port-to-port passing. At the time, the *Genesis River* was about a mile north of the Bayport Flare. Pilot 2 told investigators that, using the tools on his PPU, he knew that the *Genesis River* would pass the *BW Oak* near the southern part of the Bayport Flare. He stated that the location of the planned passing caused him no concern, as he had met other ships in this location before. Investigators spoke with other Houston Pilots, and each stated that they felt comfortable passing in that location or that it was a safe area to pass.

As the *Genesis River* transited south through the channel, its engine speed continued to slowly increase until it reached between 72 and 73 rpm, which crewmembers stated was the programmed rpm setpoint for sea speed, between an available range of 60 to 89 rpm. The vessel's speed over ground was 12 knots.

At 1509, the *Genesis River* entered the Bayport Flare from the north on a course of 161 degrees. (The base course of this section of the channel is 161.7, as defined by range markers to the south of this channel section.) At 1509:22, pilot 2 began to set up for the passing with the *BW Oak* by ordering course 163, followed 27 seconds later by an order to course 165. According to VDR data, the ship steadied on course at 1510:12. From that time, the VDR shows that the helmsman used up to 25 degrees starboard rudder input and 24 degrees port rudder input to maintain the ordered course.

As the *BW Oak* entered the turn at Five Mile Cut from the south, the pilot on board the vessel altered course at 1510:23. The *BW Oak* pilot told investigators that he ordered the turn earlier than he normally would have so that the ship would be on the starboard side of the channel when it met the *Genesis River*.

At 1511:11, pilot 2 on the *Genesis River* ordered course 164 (1 degree to port). At that time, the rudder was at 19 degrees to port, and the ship was on a heading of 166 degrees. Over the next 20 seconds, the rudder held briefly at 19 degrees to port, then shifted briefly to 14 degrees to starboard, then shifted back to port. The rudder was at port 18 degrees when pilot 2 ordered port 15 degrees rudder. Three seconds later, he ordered port 20 degrees rudder, followed by rudder midship 5 seconds after that. VDR data showed that the helmsman turned the wheel as the pilot ordered, and the rudder responded accordingly. When the pilot issued the midship order, the ship's heading was 164 degrees.

While pilot 2 was issuing these maneuvering orders, he was also having a conversation with the *BW Oak* pilot over VHF radio channel 13 about a house that had burned down in a Houston neighborhood the night before. The conversation, which began at 1511:29, consisted of five short transmissions between the two pilots and ended 16 seconds later. Pilots told investigators that it was not uncommon to have casual conversations over the radio as vessels passed each other.

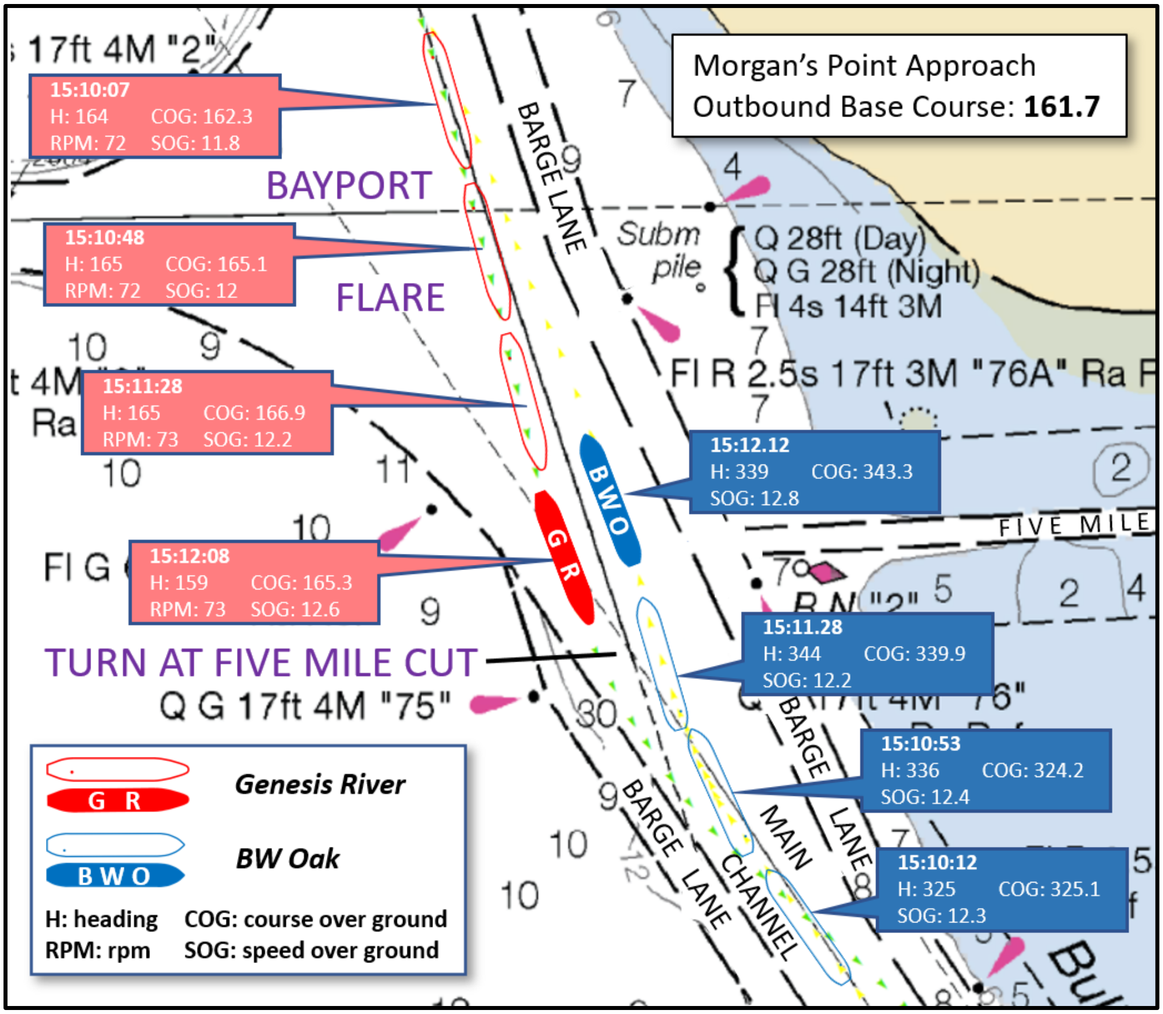

Figure 9. *Genesis River* and *BW Oak* passing in Bayport Flare. Positions based on automatic identification system (AIS) reporting data from each ship. (Background adapted from NOAA chart 11327)

At 1511:48, pilot 2 ordered port 15 degrees rudder, and the rudder moved to the ordered angle as the bow of the *Genesis River* passed the bow of the *BW Oak*. Nine seconds later, the pilot ordered rudder midship, followed almost immediately by hard starboard rudder. The helmsman repeated the command, and the rudder moved to starboard 35 degrees at 1512:07. A second later, pilot 2 ordered the rudder eased to starboard 10 degrees, followed another 2 seconds later by an order to rudder midship. The rudder began moving to midship, reaching centerline at 1512:20 just as the stern of the *Genesis River* passed the stern of the *BW Oak*. During this 32 second period, the *Genesis River*'s heading shifted 8 degrees to port, to 158 degrees.

The base course of the channel after the turn at Five Mile Cut was 146 degrees. As the *Genesis River* entered the turn, the vessel was on the green side of the main deepwater channel. The recorded water depth under the keel, which had been between 4 and 5 meters while the ship transited the Bayport Flare, reduced to 3 meters.

At 1512:25, as the ship's heading continued shifting to port and passed 155 degrees, pilot 2 ordered starboard 20 degrees rudder. The rudder moved to 20 degrees starboard until the pilot ordered the rudder back to midship at 1512:32. Five seconds later, as the ship's heading passed 151 degrees, pilot 2 ordered hard starboard rudder. The rudder moved to starboard, reaching 35 degrees at 1512:45, with the ship's heading passing 149 degrees.

After ordering the hard starboard rudder, the pilot hailed the towing vessel *Voyager* on VHF radio channel 13. The *Voyager* and its tow were inbound in the barge lane on the red side of the Houston Ship Channel, en route from the Buffalo Marine fleeting facility in Texas City, Texas, to the Kirby fleeting facility in Channelview, Texas. Both of the *Voyager*'s engines were at full throttle, and the tow was making about 5.3 knots over ground. The *Voyager*'s relief captain, who had been at the helm of the vessel since taking the watch at noon, answered pilot 2's radio call. The pilot told him, "[I'm] that ship lookin' at you. Trying to check this thing up. Just keep an eye on me." The relief captain responded, "roger, roger."

The *Genesis River*'s heading continued to swing to port. When the heading passed 143 degrees (3 degrees to port of the channel base course) at 1513:07, pilot 2 ordered the mate on watch to "gimme more rpm," and repeated the order a few seconds later. The second mate answered "yes, yes, yes." Pilot 2 told investigators that he wanted more engine rpm to increase water wash over the rudder to increase its effectiveness.

The *Genesis River*'s bow was now pointed toward the red side of the channel, directly at the *Voyager* and its tow. Pilot 2 radioed the *Voyager* again, stating, "She's not checkin' up, *Voyager*." While answering pilot 2 on the radio, the *Voyager* relief captain moved the towing vessel's throttles to neutral. "What do you need me to do, Captain?" he asked. Pilot 2 responded, at 15:13:25, "Go to the greens," meaning, the *Voyager* tow should cross the channel to the green side. The *Genesis River* had begun to cross from the green side to the red side of the channel, and, when interviewed after the accident, pilot 2 stated it was his intention for the two vessels to pass starboard side to starboard side once the *Voyager* reached the green side.

The relief captain told investigators that when pilot 2 had first called him, he considered various options should he need to maneuver to avoid the *Genesis River*. He stated that he believed that he could not stop or slow down due to vessel traffic behind him (the towing vessel *Provider*, pushing two barges ahead, was about 0.6 mile astern and transiting at a faster speed) and because he felt that stopping would still leave his vessel in the path of the *Genesis River*. He said he could not turn to starboard because there was a sunken bulkhead just outside the barge lanes. He was concerned that hitting the bulkhead with the barges would stop the tow and leave his vessel stranded in the path of the ship bearing down on him. The towing vessel was at full power, so he could not increase speed. Thus, with the *Genesis River* pointed directly at him, he felt that his only course of action was to cross the channel to the green side. He stated that the pilot's direction over the radio to do so only confirmed what he had already determined was the best action, so he immediately increased the *Voyager*'s engine throttles back to full power and put the vessel's rudders over hard to port. Automatic identification system (AIS) data showed that the head of the tow began pivoting to port, with the *Voyager* initially swinging out to starboard, at 1513:35.[12]

[12] *AIS* is a maritime navigation safety communications system. At 2- to 12-second intervals on a moving vessel, AIS automatically transmits vessel information, including the vessel's name, type, position, course, speed, navigational status, and other safety-related information, to appropriately equipped shore stations, other vessels, and aircraft. The rate at which the AIS information is updated depends on vessel speed and whether the vessel is changing

About the same time, the relief captain sounded the general alarm and radioed the deckhand on watch, telling him to find the captain to tell him to come to the wheelhouse.

Meanwhile, the *Genesis River*'s engine rpm demand signal (that is, the input to the engine control program from the EOT) and the actual engine rpm had remained at 73 rpm. Pilot 2 once again asked for more rpm, and the second officer answered "Yes, Sir; yes, sir we are going to full." A few seconds later, the pilot told the crew to summon pilot 1 to the bridge, and in response a crewmember was sent to the pilot room.

At 1513:43, 36 seconds after pilot 2's initial request for more rpm and 14 seconds after his second request, the *Genesis River* VDR recorded the second officer, speaking in his native language, talking on the ship's phone to the engine control room (ECR). He said, "Yes, sir, now give us maximum rpm, whatever you can give." The vessel's chief engineer stated that the first engineer had answered the call in the ECR from the second officer. After taking the call, the first engineer turned a fine tuner dial on the side of the ECR EOT lever, which changed the sea speed setting from 72 rpm to 85 rpm. According to the chief engineer, the second officer did not indicate that there was an emergency, and so after the first engineer adjusted the rpm setting he and the chief engineer left the ECR to tour the engine room. Parametric data from the VDR showed that the rpm demand signal did not increase after the change in setting from the ECR. The actual engine rpm sporadically registered 74 rpm, but otherwise remained at 73 rpm until just before the collision.

About 1513:46, the *Voyager* captain, who had been exercising on a treadmill in the engine room when the deckhand summoned him, arrived in the wheelhouse. He asked the relief captain what was happening, and the relief captain stated that he responded, "look!" while pointing out the wheelhouse windows to the *Genesis River*. After taking a few seconds to survey the situation, the captain asked the relief captain if he wanted the captain to take the conn. The relief captain said that he responded, "no, I got it." The captain remained in the wheelhouse to assist the relief captain.

As the *Voyager* tow turned, its speed over ground slowed, dropping as low as 3.6 knots. Pilot 2 told investigators that the tow did not turn and cross the channel as quickly as he expected. He again radioed the *Voyager*, stating "You need to go straight to the greens. Take a ninety to the greens, cuz I'm going to go your way again probably." The *Voyager* relief captain responded "roger, roger. Straight over."

course. AIS also automatically receives information from similarly equipped vessels. Coast Guard regulations require AIS in waterways governed by vessel traffic control (Title 33 *Code of Federal Regulations* Part 164).

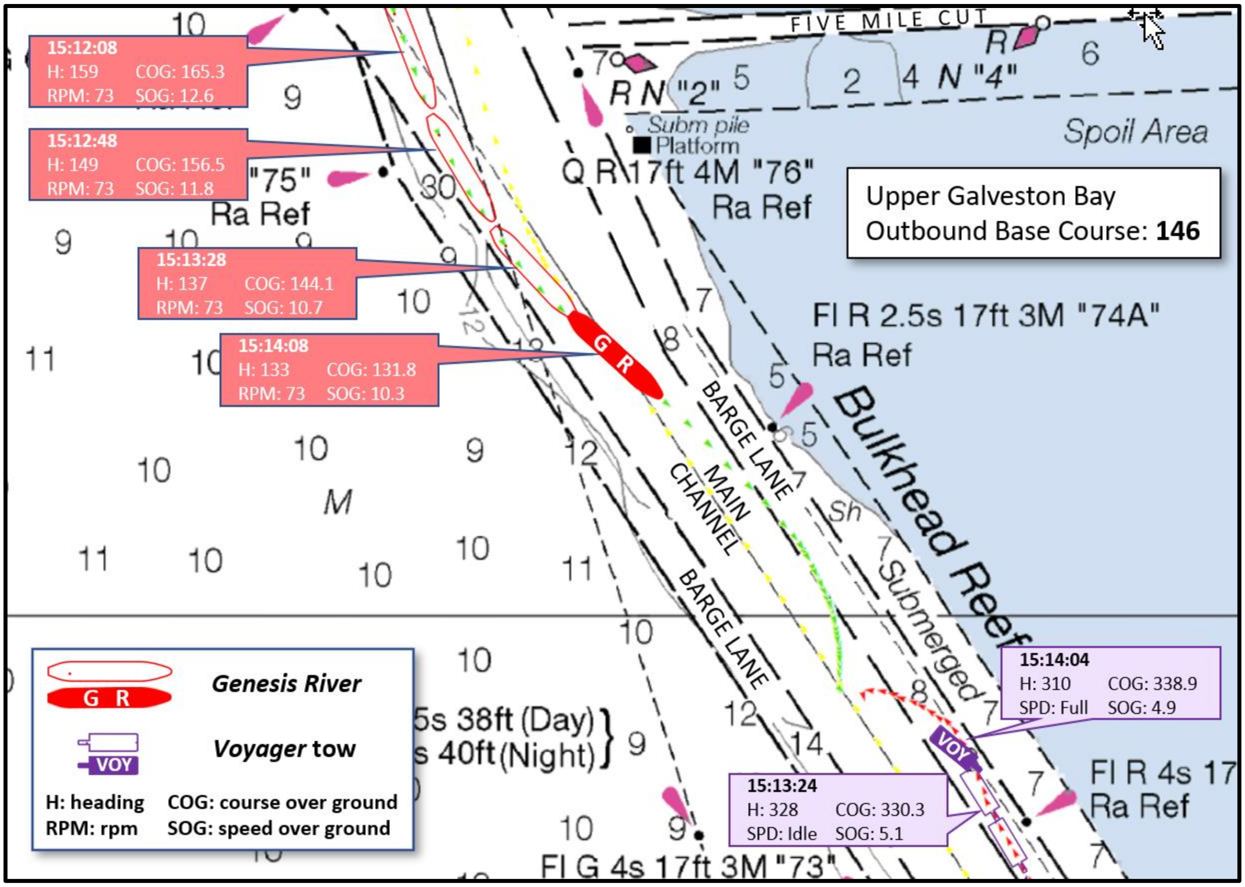

Figure 10. *Genesis River* crosses the channel as *Voyager* tow begins to turn to port. (Background adapted from NOAA chart 11327)

Meanwhile, as the *Genesis River* crossed the center of the channel toward the red side (with the water depth under the keel increasing to 5 meters), the ship's swing to port slowed and then ceased at a heading of 132 degrees. In response, pilot 2 ordered the rudder to midship, followed immediately by an order of rudder hard to port. The vessel held the 132 heading for 10 seconds, before it began swinging back to starboard, slowly at first, starting at 1514:06. The *Genesis River*'s rudder swung from starboard to port, reaching 22 degrees to port before pilot 2 issued his next order. At 1514:13, the pilot ordered the rudder to midship, then to starboard 20 degrees. Five seconds later, he ordered the rudder increased to hard starboard. The rudder swung back again to starboard, reaching 34 degrees at 1514:24.

As the *Genesis River* assigned helmsman (the AB) was monitoring the OS at the helm, he noticed that "the pilot is already in panic." Recognizing that an emergency situation was developing, he took back the helm from the OS. Seconds later, pilot 2 ordered the rudder to midship. The rudder returned to centerline at 1514:33. During these rudder movements, pilot 1, who had returned to the bridge, asked the second mate if both of the steering pumps were on line. The mate responded "yeah, already."

Pilot 2 radioed the *Voyager* again, stating "Go, *Voyager*, go! Go, go, go!" The *Voyager* relief captain responded, "I'm hooked up, hard over, there, brother."

At 1514:44, pilot 2 ordered the rudder hard to port, then repeated the order twice. During the postaccident interview, he told investigators that he knew the ship would swing back across the channel, so he ordered the port rudder to attempt to hold the ship on the red side of the channel until it had passed the *Voyager* tow. The helmsman acknowledged the order, and the rudder began swinging to port, reaching 35 degrees 8 seconds later.

By this time, the *Voyager* tow was crossing the deep draft channel, yet it was still on the red side making about 4 knots. The *Genesis River* was continuing to swing back to starboard, and pilot 2 realized that the port rudder was not going to be effective in holding the ship along the red side of the channel. Consequently, he radioed a warning to the *Voyager*. "I'm gonna probably hit ya…sound your general alarm there, Voy[ager]…get everybody up." A response from the *Voyager* was not captured on audio recordings.

At 1514:54, the *Genesis River* second mate called the master in his stateroom one deck below the bridge, telling him to come to the bridge immediately. About the same time, a cadet who had been on the bridge knocked on the master's stateroom door and delivered the same message. The master proceeded to the bridge, arriving about 30 seconds later.

At 1515:00, pilot 2 ordered the rudder to midship, then immediately ordered the rudder hard to port again. The rudder angle briefly decreased, before returning to 35 degrees to port. Ten seconds later, the pilot warned the *Voyager* again over the radio, stating, "Wake everybody up on that, uh, *Voyager*." The towing vessel relief captain responded "We got it, brother. We got 'em. Appreciate it." At 1515:12, the pilot ordered the rudder to midship again. The helmsman brought the wheel to midship, and the rudder followed, reaching centerline 7 seconds later.

The *Genesis River*'s rate of turn back to starboard increased as it approached the channel bank on the red side. As the ship passed heading 139, pilot 2 radioed the *Voyager*, "I'm gonna be swingin' your way real soon. She's comin' your way. You gotta push on it." The *Voyager* relief captain responded, "She's all she's got, there brother; all she's got."

Shortly thereafter, with the *Genesis River*'s rudder at midship, the second mate said, "Go to the port; go to the port." He told investigators that he was speaking to the pilot at the time, although the pilot did not acknowledge him.

At 1515:29, as the *Genesis River*'s heading passed 143 degrees, pilot 2 ordered the rudder to midship (the rudder was at midship), then immediately ordered the rudder to hard starboard. The helmsman acknowledged the order, and the rudder began moving to starboard, reaching 35 degrees at 1515:37. Pilot 2 told investigators that, at that point, he knew that the ship was going to collide with the tow, so he turned to starboard to ensure that the *Genesis River* struck the barges and not the towing vessel. He stated that his principal concern was the people on the *Voyager*. After issuing the starboard rudder order, he radioed the *Voyager* stating, "You got it hard over there, *Voyager*?...work with me…we're gonna collide." The *Voyager* relief captain responded back "Roger, roger. Roger, roger," while the *Voyager* captain sounded the general alarm.

As pilot 2 was struggling to control the ship, pilot 1 ran out to the port bridge wing. He told investigators that from this position, he could see that the *Genesis River* was now in the barge lane on the red side of the channel. He said, “As the bow went into the bank on the red side, the ship swung into the bank and the whole ship just rolled up…we touched bottom.”

At 1515:35, with the *Genesis River* swinging back toward the *Voyager* and its tow, the second officer said to pilot 2, “hard port, sir, hard port.” He received no reply. Eight seconds later, the pilot ordered “stop engines.” The master, who had returned to the bridge, repeated the engine order to the second officer. At 1515:49 and again at 1515:52, the sound of the engine order telegraph alarm was recorded by the VDR. After the second alarm, the rpm demand signal went to zero, and the engine rpm began to slow quickly. At 1516:03, seconds before the collision, the master ordered the engine to “crash astern” (on the Genesis River EOT, crash astern was called “Emerg. Full.”) The crash astern input to engine control system overrode the normal control program and executed an accelerated shift to maximum astern propulsion.

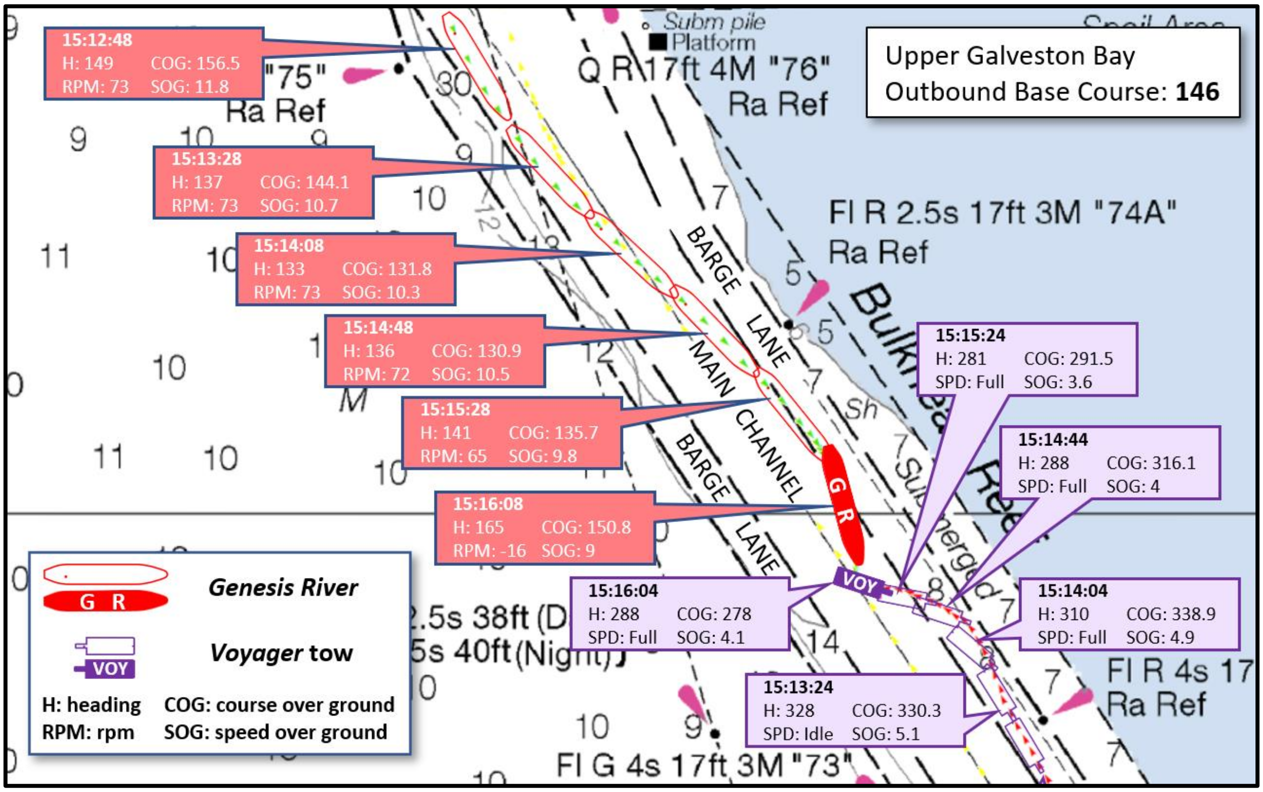

Figure 11. *Genesis River* and *Voyager* seconds before to collision. (Background adapted from NOAA chart 11327)

At 1516:09, the *Genesis River*’s bow struck barge *30015T*, breaching the number 2 cargo hold on the starboard side near the longitudinal center of the vessel and continuing through the hull into the number 2 cargo hold on the port side. The force of the collision capsized barge *MMI3041*, although no tanks were breached. When the *Genesis River* impacted the *30015T*, the port face and long wires securing the *Voyager* to the barges parted. As the barges were pushed sideways by the *Genesis River*, the *Voyager* pivoted on the starboard face wire until the towing vessel’s starboard side contacted the stern of the *30015T*. As the *Voyager* continued to be pulled, it heeled to starboard until the starboard face and long wires gave way allowing the relief captain to regain control of the vessel. The loose end of the parted starboard long wire, which had fallen into the water, then fouled the *Voyager*'s starboard propeller, stalling the engine.

Just prior to the collision, the *Voyager* captain had remembered that the engine room door on the starboard side main deck was open, and he sent the deckhand down to close it. Company policy stated that all main deck doors were to remain closed while the vessel was in operation, but the captain had opened the door to allow air into the engine room while he was exercising. The deckhand reached the door just as the *Genesis River* struck the tow. He was able to close the door, but not before about 200 gallons of water entered the engine room.

The engine on the *Genesis River* remained at crash astern, and once the forward motion of the *Genesis River* ceased, the ship began to back away from the barges. Reformate carried in the breached cargo tanks escaped into the channel from the hole in the *30015T*'s hull, eventually releasing approximately 11,276 barrels (473,600 gallons) into the waterway. Pilot 2 radioed the Houston Pilots dispatcher, stating "Bad collision. Shut down the channel." Pilot 1, who had begun communicating with the Coast Guard Sector Houston-Galveston Vessel Traffic Service (VTS) via his cellular phone when the collision was imminent, informed Coast Guard VTS about the accident. Pilot 1 stated that he had initially attempted to use VHF channel 13 to contact VTS but could not due to heavy radio traffic from other users.

Once the vessels were clear of each other, pilot 1 radioed the *Voyager* crew to check on their status. The relief captain radioed back that the crew was okay. The *Genesis River* anchored in the channel, awaiting further direction from VTS, while the *Voyager*, reduced in maneuverability due to the loss of the starboard engine, made up to the towing vessel *Provider*. The *Genesis River* was eventually directed to a lay berth in Bayport, and the vessel proceeded to the berth under its own power, mooring at 1736 that evening. The *Voyager* was towed to the Kirby facility at Old River, Texas, arriving at 2120. The barges remained where they had been following the collision while response operations commenced.

When interviewed the week following the accident, pilot 1 and pilot 2 stated that the helmsmen had responded to their rudder orders as expected throughout the voyage. Pilot 1 noted that the AB at the helm would sometimes require 10 to 15 degrees rudder to maintain a steadying course, stating further, "they had a very good quartermaster." (Quartermaster is an alternate term for helmsman.)

At a Coast Guard hearing held 4 months after the accident, pilot 2 stated that after he had reviewed the evidence from the accident, he believed that the OS who had been at the helm just prior to the collision had not properly executed his rudder commands. According to pilot 2, when he gave two rudder commands in quick succession, the OS would fully execute the first command before executing the second command. (In standard practice, a follow-on command supersedes the previous command and should be executed immediately.) Pilot 2 said, "He was always trying to execute the previous helm command. He was one helm command behind me. He wasn't doing the proper orders given."

During postaccident interviews, both pilot 1 and pilot 2 told investigators that the crew responded to engine orders as expected. Pilot 1 stated "whenever I needed an engine order, that man was right there to push the buttons." However, during the Coast Guard hearing, pilot 2 stated that, when he was trying to regain control of the vessel prior to the collision, "I did not get the rpms…that I asked for."

Also during the Coast Guard hearing, pilot 2 was asked whether it would have been prudent for the *Voyager* to have turned to starboard, instead of to port, when maneuvering in an attempt to avoid the accident. Pilot 2 responded, "Absolutely not…I believe very strongly that I would have killed guys that day had the *Voyager* went to the right."

4 Response Operations

When the accident was reported to the VTS, the Coast Guard captain of the port closed the Houston Ship Channel to navigation. At 1541, the incident command system (ICS) was activated and an incident command post (ICP) was established at Coast Guard Sector Houston-Galveston headquarters (the ICP would later move to a location near Bayport). At the same time, Kirby Inland Marine implemented its spill response plan, hiring various providers to conduct response operations. By 1935, oil spill containment booms had been deployed around barges *30015T* and *MMI3041,* and additional booms were being installed across inlets and other sensitive marine areas around Galveston Bay. Oil skimmers were deployed to recover reformate/water mixture in the vicinity of the accident site, with a total of seven skimmers used during the cleanup.

At 0800 on Saturday morning, drone footage of the accident site showed a light sheen on the water originating from barge *30015T* and extending 0.5 miles to the southwest. By 1230 Saturday, tugboats and spud barges were positioned alongside the two barges to stabilize and prepare them for offloading of the remaining reformate cargo.

Cleanup efforts continued. Residents in neighborhoods surrounding Galveston Bay reported a petrochemical odor, prompting air quality testing in the areas most affected. Throughout the response, 15,016 air samples were collected measuring for concentrations of benzene, volatile organic compounds (VOCs), or atmospheric flammability as a percent of the lower explosive limit (%LEL). Thirty-nine readings detected benzine or VOCs at or above 0.5 parts per million, but secondary readings for these instances determined that levels were not sustained above Unified Command-approved action levels. A fishkill impacting between approximately 100 and 1,000 fish, shrimp, and crabs occurred on a limited stretch of shoreline was reported, along with other wildlife impacts. Out of 2,700 water samples taken between Friday (the accident day) and Sunday, none showed pollution levels requiring action.[13] A nearby waterfront park was closed and private oyster harvesting in some areas of Galveston Bay was halted for several days following the accident.

At 0400 on Sunday, the captain of the port opened the Houston Ship Channel for navigation to outbound traffic only. At 1505 that day, lightering of reformate cargo from barge *30015T* commenced. Lightering of the barge would continue, with operational breaks, through 2345 on Tuesday, May 14. In all, 14,000 barrels of pure reformate and 4,530 barrels of reformate/water mixture were recovered from the vessel. Once the offload was completed, the barge was towed to a shipyard in Channelview for assessment.

[13] Wesner Childs, Jan, "Houston Shipping Channel Ship Collision Cleanup Continues After Toxic Spill, Reports of Fish Kill," *weather.com*, May 2019.

Offloading of cargo from the capsized barge *MMI3041* proved more difficult. At 1911 on Monday, May 13, a small opening was made in the hull of the overturned vessel to confirm that the atmosphere within was not explosive. The following day, the barge—still capsized—was towed to a location off the main channel (allowing the channel to reopen for navigation of two-way traffic on May 15). At 1447 on Tuesday, divers completed making connections for lightering of the barge. Lightering commenced at 1900 and was completed at 1710 the next day. On Sunday, May 26, the *MMI3041* was parbuckled—righted using rotational leverage—and towed to the shipyard in Channelview. Nearly all of the 25,392 barrels of reformate cargo was recovered from the *MMI3041* during lightering, with the remaining 150–180 barrels recovered after parbuckling.

5 Vessel Damage

The collision opened an S-shaped gash in the *Genesis River* hull about 7.5 feet (2.3 m) below the waterline and 36 feet (11 m) aft of the bow on the starboard side, causing the vessel's fore peak tank to flood. The estimated cost of repairs to the *Genesis River* was $406,000.

Barge *30015T* sustained a 23-foot-by-30-foot triangular shaped hole in the starboard side, as well as bent or broken plating, framing, and piping throughout the vessel. Barge *MMI3041* sustained inset or buckled plating along wing tanks on both sides of the vessel. Additionally, several holes were made in the hull during salvage operations. Both barges were later determined to be constructive total losses and scrapped, with a combined insured value of $2,789,643.

6 Additional Information

6.1 Personnel

6.1.1 Houston Pilots

The Houston Pilots are an association of ship pilots licensed by the state of Texas and the Coast Guard to serve on vessels transiting the Houston Ship Channel. The Board of Pilot Commissioners for the Ports of Harris County, Texas, oversees the Houston Pilots. According to the Houston Pilot's Presiding Officer, each pilot is "an independent contractor." State law requires the completion of a 3-year deputy training period before licensing as a full branch pilot, and deputies are trained via a standardized program. Full branch pilots share resources such as pilot boats and centralized dispatching services. The Houston Pilots have developed and maintain a publication entitled *Navigation Safety Guidelines for the Houston Ship Channel*. According to the publication, the guidelines "represent the collective experience and judgement of the state licensed Pilots for Harris County ports and have been developed to ensure the safe and efficient movement of vessels on the Houston Ship Channel and its navigable deep draft tributaries." The pilots aboard the *Genesis River* and *BW Oak* were members of the Houston Pilots. The *Voyager* did not have and was not required to have a pilot on board.

Genesis River Pilot 1. Pilot 1 had the conn of the *Genesis River* for the first half of the Houston Ship Channel transit and had turned over to pilot 2 prior to the accident. After the turnover, he went to the pilot's room where he remained until just before the collision, when he was called to the bridge by pilot 2. Pilot 1 held a valid US Coast Guard credential as a First Class Pilot of Vessels of Any Gross Tonnage Upon the Houston Ship Channel and a valid commission from the State of Texas as a Branch Pilot, the Houston Ship Channel and Galveston Bar. Pilot 1 told investigators that he had 38 years' experience as a credentialed merchant mariner. He was accepted into the Houston Pilots in 1995, and, after completing a 2-year training program as a deputy pilot, was designated a full pilot in 1997.[14] At the time of the accident, he had made 5,680 transits as a pilot on the Houston Ship Channel and surrounding waters. Pilot 1 stated that he had completed a bridge resource management for pilots course about 2 years prior.

Genesis River Pilot 2. Pilot 2 had the conn of the *Genesis River* during the accident. He held a valid US Coast Guard credential as a First Class Pilot of Vessels of Any Gross Tonnage Upon the Houston Ship Channel and a valid commission from the State of Texas as a Branch Pilot, Houston Ship Channel and Galveston Bar. Pilot 2 told investigators that he had about 22 years' experience as a credentialed merchant mariner. He had 13 years' experience as a Houston Pilot: 3 years as a deputy pilot and 10 years as a full pilot. At the time of the accident, pilot 2 had made 1,947 transits as a full pilot on the Houston Ship Channel. He stated that he had completed a bridge resource management course but could not recall if the course had been specifically designed for pilots or when he had completed the course.

BW Oak Pilot. The *BW Oak* pilot had the conn of the vessel as it passed the *Genesis River* just prior to the accident. He held a valid US Coast Guard credential as a First Class Pilot of Vessels of Any Gross Tonnage Upon the Houston Ship Channel and a valid commission from the State of Texas as a Branch Pilot, Houston Ship Channel and Galveston Bar. He told investigators that he had about 30 years' experience as a credentialed merchant mariner. He was accepted into the Houston Pilots in 1997, and, after completing a 2-year training program as a deputy pilot, was designated a full pilot in 1999. At the time of the accident, the *BW Oak* pilot had made 4,509 transits as a full pilot on the Houston Ship Channel. He stated that he had completed a bridge resource management course but could not recall if the course had been specifically designed for pilots or when he had completed the course.

6.1.2 *Genesis River* Crew

Master. The master of the *Genesis River* was in his cabin from about 1345 until just prior to the accident, when he was called to the bridge by the crew. The master held a valid Certificate of Competency as Master of a Foreign-going Ship issued by the Government of India. He had 17 years of sailing time as a merchant mariner, with nearly 10 years' experience as a master. At the time of the accident, he had been master of the *Genesis River* for 3 months. Because this was a new ship, he had not previously served as master on board, although he had captained the *Crystal River*, a sister-vessel to the *Genesis River*, for 4 months. The master told investigators that he had served as master on two other smaller company vessels as well. He stated that he had transited the Houston Ship Channel as master of a vessel about three times. According to records provided by the company, the *Genesis River* master completed a Refresher and Updating Training for Deck Officers (Operational Level, Management Level) course in 2014. He last completed a bridge resource management/bridge team management (BRM/BTM) with ship simulator course in 2016. According to the master, the BRM/BTM course he attended included training involving operations in coastal waters with pilots.

[14] At the time that pilot 1 was accepted into the Houston Pilots, the training period as a deputy pilot was 2 years in length. The training period was lengthened to 3 years in the period between when pilot 1 and pilot 2 joined the association.

Chief Officer. The chief officer of the *Genesis River* had been the senior officer on the bridge of the vessel until the master returned just prior to the collision. The chief officer held a valid Certificate of Competency as Master of a Foreign-going Ship issued by the Government of India. He told investigators that he had about 18 years of sailing time as a merchant mariner. He joined the *Genesis River* in February 2019 and had not served on the ship before. He had previously served as the chief officer on a very large crude carrier (VLCC) and another LPG carrier (not a sister-ship to the *Genesis River*). According to records provided by the company, the *Genesis River* chief officer last completed a BRM/BTM with ship simulator course in 2018. The chief officer stated that the BRM/BTM course included training involving operations with a pilot on board.

Second Officer. The second officer was the officer of the watch during the accident and was responsible for monitoring the ship's position and the actions of the watch team. He also operated the engine order telegraph when ordered by the pilot and master. He held a valid Certificate of Competency as Second Mate of a Foreign-going Ship issued by the Government of India. He told investigators that he had 8 years of sailing time as a merchant mariner, with 18 months served as a second officer. He joined the *Genesis River* when it was delivered from the build-yard to the company, about 6.5 months prior to the accident. He had previously served as the second officer on an ammonia carrier and two LPG carrier sister-ships of the *Genesis River*, the *Fountain River* and the *Galaxy River*. He stated that he had transited the Houston Ship Channel 15–20 times, 5–6 times as second officer. According to records provided by the company, the *Genesis River* second officer completed a Refresher and Updating Training for Deck Officers (Operational Level) course in 2016 and last completed a BRM/BTM course in 2018. The second officer told investigators that the BRM/BTM course included training involving operations with a pilot on board.

Able-bodied Seaman. An able-bodied seaman (AB) was the assigned helmsman during the accident voyage. The AB had the helm from the time the vessel got under way until about 1500, when an OS was allowed to take the helm under the supervision of the AB. The AB held valid certificates for Ratings Forming Part of the Navigation Watch and Able Seafarer Deck issued by the Government of the Republic of the Philippines. He told investigators that he had 8 years of sailing time as a merchant mariner and had served on 8 different ships. He had been a helmsman on four ships, including the *Grace River*, a sister-vessel to the *Genesis River*. He joined the *Genesis River* at delivery, about 6.5 months prior to the accident.

Ordinary Seaman. The ordinary seaman (OS) that took the helm prior to the accident held valid certificates for Ratings Forming Part of the Navigation Watch and Able Seafarer Deck issued by the Government of the Republic of the Philippines. As such, he was qualified by international standards to stand a helmsman watch. He told investigators that he had 5 years of sailing time as a merchant mariner and had served on three different ships—one being a sister-ship of the *Genesis River*, the *Summit River*. In 2014 he had completed a ship steering course provided by the company, and he was training to be promoted to an AB position with the company. He joined the *Genesis River* at delivery, about 6.5 months prior to the accident, and had been training on the helm for 2–3 months, standing 1.5–2 hour watches a day, 4–5 times a week. The OS stated that he had previously steered the *Genesis River* for training on both inbound and outbound transits of the Houston Ship Channel.

6.1.3 *Voyager* Crew

Captain. The captain of the *Voyager* was overall in charge of the vessel. He was not on watch during the accident but came to the wheelhouse when the relief captain sounded the general alarm prior to the collision. He held valid US Coast Guard credentials as a Master Of Towing Vessels Upon Great Lakes, Inland Waters and Western Rivers and a Master Of Self-Propelled Vessels Of Less Than 200 Gross Register Tons (GRT) Upon Inland Waters. The captain told investigators that he had been employed with Kirby Inland Marine for 16 years, 7 years as a captain on board the *Voyager*. He stated that he had made over 100 transits of the Houston Ship Channel. He said that he attended Wheelhouse Pilot Management, as well as other training courses including simulators, on a recurring basis every 3 years. The captain's normal work rotation was 21 days on the vessel followed by 10 or 11 days off. He had been scheduled to be off cycle starting on May 3 but had requested and been granted an extension to remain on board as captain for an additional 7 days. He was due to be relieved at the completion of the accident voyage.

Relief Captain. The relief captain was second overall in charge of the *Voyager* and was at the helm during the accident. He held a valid US Coast Guard credential as a Master Of Towing Vessels Upon Great Lakes, Inland Waters and Western Rivers. The relief captain told investigators that he had been employed with Kirby Inland Marine, working on towing vessels and barges, for nearly 21 years. He had been a wheelman (a crewmember qualified to conn the vessel) for 13 years and a relief captain on the *Voyager* for 12 years. He stated that he had made the inbound transit of the Houston Ship Channel "hundreds" of times. He said that he had last attended a bridge resource management course in 2016. The relief captain's normal work rotation was 21 days on the vessel followed by 10 or 11 days off. On the day of the accident, he was on the 16th day of his work cycle.

6.2 Work, Rest and Sleep History

6.2.1 Houston Pilots

Genesis River Pilot 1. Work/rest/sleep records for pilot 1 were not collected after the accident because he was not at the conn during the collision and did not affect its outcome. When interviewed, pilot 1 told investigators that he got about 8 hours of sleep overnight before the accident voyage, waking at 0930. He stated that he drank one caffeinated beverage (iced tea) on the day of the accident, while he was on the ship.

Genesis River Pilot 2. According to information submitted to the Coast Guard, pilot 2 had 23 hours sleep in the 72 hours previous to the accident and had slept 9 hours the night before the collision. He had worked about 15.5 hours over the same period. He told investigators that he had consumed no alcohol the night before and his sleep had been "really good." He stated that he drank two to three cups of coffee after waking up in the morning, a "5-hour ENERGY" drink while pilot 1 had the conn of the *Genesis River*, and an additional cup of coffee when he took the conn.

BW Oak Pilot. According to information submitted to the Coast Guard, the *BW Oak* pilot had 28.5 hours sleep in the 72 hours previous to the accident and had slept 10.5 hours the night before the accident. He had worked about 13 hours over the same period.

6.2.2 *Genesis River* Crew

Master. A work/rest log provided by the company showed that the master had 24.5 hours of work and 47.5 hours of rest in the 72 hours prior to the accident. The International Maritime Organization (IMO) standard form used to log work and rest did not specify times of sleep during the rest periods. The master told investigators that the night before the accident, he had gone ashore with the second officer and first assistant engineer, and, between 2130 and 2230, he consumed three alcoholic drinks (beer) while ashore. The master stated that he and the other crewmembers had intended to return to the ship at midnight but could not find a taxi due to heavy overnight storms. They eventually returned to the ship about 0400, and the master went to sleep immediately thereafter. He was awoken between 0930 and 1000 to review cargo documentation. He stated that the quality of his sleep was "good." The master drank one cup of coffee on the morning of the accident. During the accident voyage, the master left the bridge at about 1345, ate lunch, and then went to his cabin. He stated that while in his cabin, he took a nap, sleeping for about 45 minutes and waking when the second officer called him to report the impending accident.

Chief Officer. The IMO standard form work/rest log provided by the company showed that the chief officer had 27.5 hours of work and 44.5 hours of rest in the 72 hours prior to the accident. He remained aboard the ship the night before the accident and had drunk no alcoholic beverages on May 9 or 10. According to the work/rest log, he had 10 hours of rest between 1430 on the May 9 and 0030 on May 10. He then worked for 1.5 hours, had another rest period for 2.4 hours, then worked from 0430 to 0830. He could not recall the exact number of hours of sleep he had that night but described it as "a good rest." The chief officer stated that he took a 30-minute nap on the morning of the accident, after cargo documentation had been completed and before the vessel got under way, and the work/rest record shows a period of rest between 0830 and 1000. The chief officer worked from 1000 onward through the accident period. He stated that he had one cup of coffee in the morning prior to leaving port.

Second Officer. The work/rest log for the second officer that was provided by the company showed that he had 28.5 hours of work and 43.5 hours of rest in the 72 hours prior to the accident. The hours of work listed in the standard IMO form corresponded to a regular watch/duty schedule of 0000–0430 and 1200–1700 daily and included an entry for a 0000–0430 watch on the morning of the accident. However, the second officer told investigators that between about 2200 the night before and 0400 that morning he had been "on shore leave" with the master. He said that he did not drink any alcoholic beverages while ashore. The form notes that the second officer began his day watch on the accident date 1 hour early, at 1100, prior to getting under way. The second officer stated that, between 0400 and 1100, he had slept. He described the quality of his sleep as "sound." He said that he drank no caffeinated beverages before the accident.

Able-bodied Seaman (AB). The IMO standard form work/rest log provided by the company showed that the AB had 24 hours of work and 48 hours of rest in the 72 hours prior to the accident. His hours of work corresponded to a regular watch/duty schedule of 0000–0400 and 1200–1600 daily. The AB stated that he had about 6–7 hours of sleep the night before the accident, which he described as "good sleep." He said that he did not drink any alcoholic beverages while the ship was in port and did not drink any caffeinated beverages on the morning of the accident.

Ordinary Seaman (OS). The IMO standard form work/rest log provided by the company showed that the OS had 27 hours of work and 48 hours of rest in the 72 hours prior to the accident.

His hours of work corresponded to a regular watch/duty schedule of 0400–0800 and 1600–2000 daily, as well as additional hours of work beginning at 1200 on the accident date related to deck operations for getting under way and his training watch on the helm. The OS said that he got about 6 hours of “good sleep” prior to his 0400–0800 cargo watch on the accident date. He also stated that he had napped for about 20–30 minutes after his morning watch, prior to going to his station for getting under way.

6.2.3 *Voyager* Crew

Captain. A work/rest record provided by the company for the credentialled crewmembers of the *Voyager* was divided by on-watch and off-watch time. The record showed that the captain had 36 hours on watch and 36 hours off watch during the 72 hours prior to the accident, which corresponded to his regular watch schedule of 0500–1200 and 1700–2200 daily. He told investigators that he had slept about 6.5 hours before his morning watch on the accident date, and the quality of his sleep was “good.”

Relief Captain. The work/rest record provided by the company showed that the relief captain had 36 hours on watch and 36 hours off watch during the 72 hours prior to the accident, which corresponded to his regular watch schedule of 1200–1700 and 2200–0500 daily. He stated that he had slept about 6 hours on the morning of the accident before assuming the watch, and the quality of his sleep was also “good.” He did not drink any caffeinated beverages prior to or during his afternoon watch.

6.3 Toxicology

6.3.1 Testing Requirements for Alcohol and Other Drugs

Per Title 46 *Code of Federal Regulations* (CFR) Part 4.06-3, mariners involved in a serious marine incident must be tested for the presence of alcohol or other drugs. Alcohol testing must be completed within 2 hours of the incident and is not required more than 8 hours after the incident. Drug testing must be completed within 32 hours of the incident, unless precluded by safety concerns directly related to the incident.

6.3.2 Houston Pilots

Pilot 1 and pilot 2 were tested for alcohol about 1900 on the accident date after disembarking the *Genesis River*. Results were negative. The *Genesis River* pilots were also tested for the presence of other common drugs, with negative results. The *BW Oak* pilot was not tested for drugs or alcohol.

6.3.3 *Genesis River* Crew

About 1800 on the accident date, after the *Genesis River* had moored in Bayport, all crewmembers on the *Genesis River* were tested for the presence of alcohol, and the results were negative. Later that evening, the crew was tested for the presence of other common drugs, and the results were also negative. As noted in section 6.2.2 above, the master stated that between 2130 and 2230 the night before the accident, he had consumed three bottles of beer. The chief officer, when he met the master on his return to the vessel about 0400 on the accident date, testified in a legal deposition that he could not smell alcohol on the master’s breath and that the master “appeared normal.”

6.3.4 *Voyager* Crew

Between 1800 and 1832 on the accident date, all four members of the *Voyager* crew were tested for the presence of alcohol. All results were negative. The crew was also tested for the presence of other common drugs, with negative results.

6.4 *Genesis River* Voyage Data Recorder

The *Genesis River* was required to carry a VDR under Regulation 20 of SOLAS Chapter V. The vessel's VDR was a JCY-1900 VDR system manufactured by Japan Radio Co. (JRC). It was capable of recording navigation, propulsion, control surface, alarm, and AIS data, as well as bridge audio and communications audio channels. A performance test was conducted on the *Genesis River*'s VDR in October 2018 (prior to the ship's delivery), and the resultant ABS certificate of compliance indicated that the equipment was being maintained in the appropriate operational condition. Approximately 12 hours of fair quality audio and 22.5 hours of parametric data were extracted from the VDR following the accident.

When the timestamps associated with the extracted audio recording were correlated to the timestamps of the extracted parametric data, a delay was noted between the audio recording and the parametric data logging. Thus, when the VDR data was played back using the manufacturer supplied software, parametric data such as changes to the position of the rudder angle indicator or the EOT position were not registered until several seconds after audio indicators corresponding to the changes. The delay between the audio and parametric data was consistent throughout the *Genesis River*'s entire transit of the Houston Ship Channel, from the Targa Terminal to the accident location.

In order to correlate events during the accident, the delay between the audio and parametric data was rectified by aligning aural cues in the audio recording with their associated parameter in the recorded data. Specifically, the timing of an audio alarm that sounded when the EOT lever was moved was aligned with the associated change in the rpm demand parameter (the EOT input signal) recorded by the VDR parametric data. A representative sample of engine rpm commands was taken, and the average of their time differences was implemented. This resulted in moving the recorded audio forward by 8.1 seconds from their original associated timestamps.

6.5 *Genesis River* Engineering and Anchor Equipment

6.5.1 Engineering

The *Genesis River*'s main propulsion system was comprised of a single centerline-mounted slow-speed, two-stroke, crosshead type Kawasaki-MAN B&W 7S60ME-C8.2 turbocharged diesel engine directly connected to a fixed-pitch, 5-bladed, 7.3-meter-diameter propeller. The engine was described by its manufacturer as "super long stroke" and had 7 cylinders, each with 600 millimeter diameter bores.[15] Due to the slow rotational speed of the engine, the propulsion system did not require a reduction gear between the engine and propeller. The engine's maximum continuous

[15] MAN Diesel & Turbo, *MAN B&W S60 ME-C8.2-TII Project Guide, Electronically Controlled Two-stroke Engines, Edition 0.5,* Denmark: MAN Diesel & Turbo SE, 2014.

output (MCO) was rated at 17,567 hp (13,100 kW) at 89 shaft rpm, and its normal output (85% MCO) was rated at 14,939 hp (11,140) at "about" 84 rpm.

The system did not use a clutch to engage or disengage the engine from the propeller or a shaft brake to stop it. The engine had to be stopped to stop the propeller and had to be started again in either the ahead or astern direction to meet the ordered speed command. Starts were accomplished by admitting compressed air into the engine cylinders in a sequence designed to turn over the engine in the desired direction. The maximum number of consecutive starts/changes in engine direction was 16, according to the pilot card.

Figure 12. *Genesis River* bridge EOT lever.

In addition to a local controller in the engine room, the main propulsion engine could be controlled from either the bridge or the ECR via a Nabtesco M-800-V Main Engine Remote Control System. The user interface at both remote locations were identical and included an EOT lever and a small control panel. The EOT lever controlled the direction of the engine (and thus, the propeller shaft), either ahead or astern, and the position of the lever set the rpm of the engine. Next to the lever was a scale divided into the standard engine orders of stop, dead slow, slow, half, and full, and a pointer attached to the EOT lever showed the position of the lever corresponding to these speed divisions. In the ahead direction, the scale also included an engine order of "Nav. Full," which corresponded to sea speed, as previously discussed in this report. In the astern direction, the scale included an engine order of "Emerg. Full," which corresponded to crash astern, as previously described in this report. As the telegraph lever was moved ahead or astern, detents stopped the lever at set rpm speeds for each standard engine order. A fine tuner dial on the side of the lever allowed the user to then make small adjustments to the rpm. In normal practice while in maneuvering mode, the fine tuner was not utilized, and the telegraph operator moved the lever to the detented position corresponding to the given order.

Figure 13. *Genesis River* bridge control panel for remote engine control system

The control panel for the system included a liquid crystal display (LCD) and several illuminated pushbutton switches. The LCD provided various system parameters, such as engine rpm and start air pressure, as well as alarm indications in the case of a system malfunction. When engine speed was changed, the rpm value of the ordered speed was displayed on the LCD. The pushbutton switches initiated various normal and emergency actions, such as starting and stopping the engine, and shifting control of the engine between the engine room, ECR, and bridge.

When in bridge control, the EOT directly controlled the engine, and any changes in the ECR EOT position would have no effect on speed. However, according to the Nabtesco specification sheet for the system installed on the *Genesis River*, the maximum rpm that could be ordered by the bridge EOT was limited by the rpm setting at the ECR EOT. If the position of the EOT lever on the bridge was set higher than the ECR EOT, the engine speed would not exceed the ECR limit EOT, and an indication of “LIMITED SPEED” would be displayed at the unit on the bridge. Thus, when the engine was operating at the limited speed and increased rpm was required, bridge watchstanders had to call the ECR to request an increase to the limit.

While in maneuvering mode (between stop and full ahead/astern), changes in the ordered speed of the engine from the EOT resulted in a rapid change in the actual engine speed (120 rpm/minute), with shaft rpms reaching the desired speed usually within seconds of the order, depending on the magnitude of the speed change. When the EOT was increased to Nav. Full (sea speed) ahead or the rpm order was increased within the Nav. Full range (between 60 and 89 rpm), a control program was initiated that increased rpm at a measured rate until the desired rpm was reached. The control program was also initiated when the engine was slowed within or from the Nav. Full range.

The control program function was to protect the engine against overload conditions and avoid of high thermal stresses and excessive vibration. When in effect, a “LOAD UP/DOWN PROGRAM” indicator illuminated on the system control panels on the bridge and in the ECR. Depending on the ordered rpm and the load on the engine, it could take up to 40 minutes under the load program to reach an ordered rpm in Nav. Full, according to the *Genesis River* chief engineer. (When the *Genesis River* increased speed to Nav. Full on the accident date, it took 21 minutes to increase rpm from 60 to 72.) Additionally, according to the control system manufacturer, the maximum rpm could also be limited by a high engine load, potentially resulting in a lower speed than ordered by the operator.

When immediate changes to engine rpm were required while the vessel was operating in the Nav. Full range, the control program could be bypassed by depressing a button on the control panel on the bridge or in the ECR. When the “PROGRAM BYPASS” button was depressed, the engine system was designed to increase speed immediately. The chief engineer stated that, when increased rpm was requested from the bridge just prior to the collision, the program bypass button was not pressed because the ECR was unaware that it was an emergency. Furthermore, the chief engineer said that it was the responsibility of the bridge watchstanders to press the bypass button, since they had the understanding of the maneuvering situation. At the time of the accident, the engine was in bridge control.

In a deposition taken in October 2019, the second officer stated that he did not depress the bypass button because “we might lose our engines in the middle of the channel…it could have created a drastic changes of major -- major damage to the engine.” Further, the second officer stated that he had been trained by the vessel’s current and former chief engineers that depressing the button would damage the engine, and that pressing the button required the permission of the master or chief officer. The chief officer also stated in a deposition that depressing the bypass button could result in engine failure “in extreme cases.”

As previously noted, setting the telegraph to Emerg. Full (crash astern) resulted in an accelerated reversal of the engine. During sea trials testing of a sister ship (the *Sumire Gas*), when crash astern was initiated with the vessel moving at a forward speed of 12.5 knots, it took about 3 minutes 22 seconds for the shaft to be stopped from turning in the forward direction and another 1 minute 53 seconds before the shaft was rotating at full speed in the astern direction. The total time that it took for the ship to come to a stop was 7 minutes 31 seconds at a distance traveled of 1 mile (1,854 m). The crash astern trial on the sister ship test was conducted in open water (sea depth greater than 200 m). Because the hydrodynamic effects of a shallow water channel affect a ship’s maneuvering characteristics, the results of the sea trial do not directly correlate to the expected performance of the *Genesis River* in the Houston Ship Channel. Pilot 2 told investigators that he considered ordering crash astern while he worked to regain control of the vessel prior to the collision, but once the *Voyager* tow began crossing to the green side, he chose not to order crash astern so that he could maintain steering control.

6.5.2 Anchors

The *Genesis River* had anchors on either side of the bow, with 13 shackles of chain on the port anchor and 12 shackles of chain on the starboard anchor.[16] The anchor windlass associated with each anchor chain had a brake holding force of 232.2 metric tons.

During the accident voyage, a deck crew was stationed at the bow of the *Genesis River* to release either or both anchors if the need arose. When interviewed after the accident, pilot 2 stated that he considered dropping the anchors to slow the ship prior to the collision but chose not to. He stated, “at that kind of speed, that kind of momentum, you’ve got the guy on the bow, drop of the anchors is very unsafe. And once you do that you have no control whatsoever of that vessel.” Pilot 1 was asked by investigators if, when he arrived on the bridge just prior to the collision, he thought about recommending dropping one of the anchors. He responded, “No…at that speed, you’d rip it right off.”

[16] A *shackle*, also called a *shot*, of anchor chain is 15 fathoms (90 feet) in length.

6.6 Environmental Conditions

At the time of the accident, the National Oceanic and Atmospheric Administration (NOAA) weather station at Morgan's Point (station MGPT2)—about 5 miles north of the collision location—recorded winds from the east at 10 knots, gusting to 12 knots. The air temperature was 74° F, and the water temperature was 75° F. At Houston's William P. Hobby Airport, located approximately 17 miles west of the accident site, visibility was reported at 10 miles or more, with scattered clouds at 2,000 feet above ground level. These weather conditions were consistent with the conditions reported by the *Genesis River* pilots during postaccident interviews.

On the night of 9–10 May, over 4 inches of rain had fallen in the Houston area. Pilot 1 noted that while the *Genesis River* transited the upper Houston Ship Channel, it was affected by strong currents near the outflows of tributaries to the channel, likely the result of the heavy rainfall. The closest current observations were from the Fred Hartman Bridge, located in the upper Houston Ship Channel (station G0810)—approximately 7 miles north-northwest of the collision and 2 miles northwest of Morgan's Point. At 1531, the current was observed at 0.55 knots from the southeast, which is consistent with a flood tide.

When the accident occurred, the tide in Galveston Bay was nearing the end of the flood tide. The *Voyager* relief captain stated that when he had taken the watch on the vessel about noon, the flood tide was noticeable, but by the time of the collision, it was "slowing down, becoming slack." The predicted tide level at the Morgan's Point NOAA station at 1530 on the date of the accident was 1.73 feet above mean lower low water level (MLLW); however, the observed level was 3.14 feet above MLLW.[17] The predicted range of tide was 1.70 feet, and the actual range of tide was 2.13 feet.

[17] *MLLW* is the average of the lower low water height of each tidal day observed over the National Tidal Datum Epoch. For stations with shorter series, comparison of simultaneous observations with a control tide station is made in order to derive the equivalent datum of the National Tidal Datum Epoch.